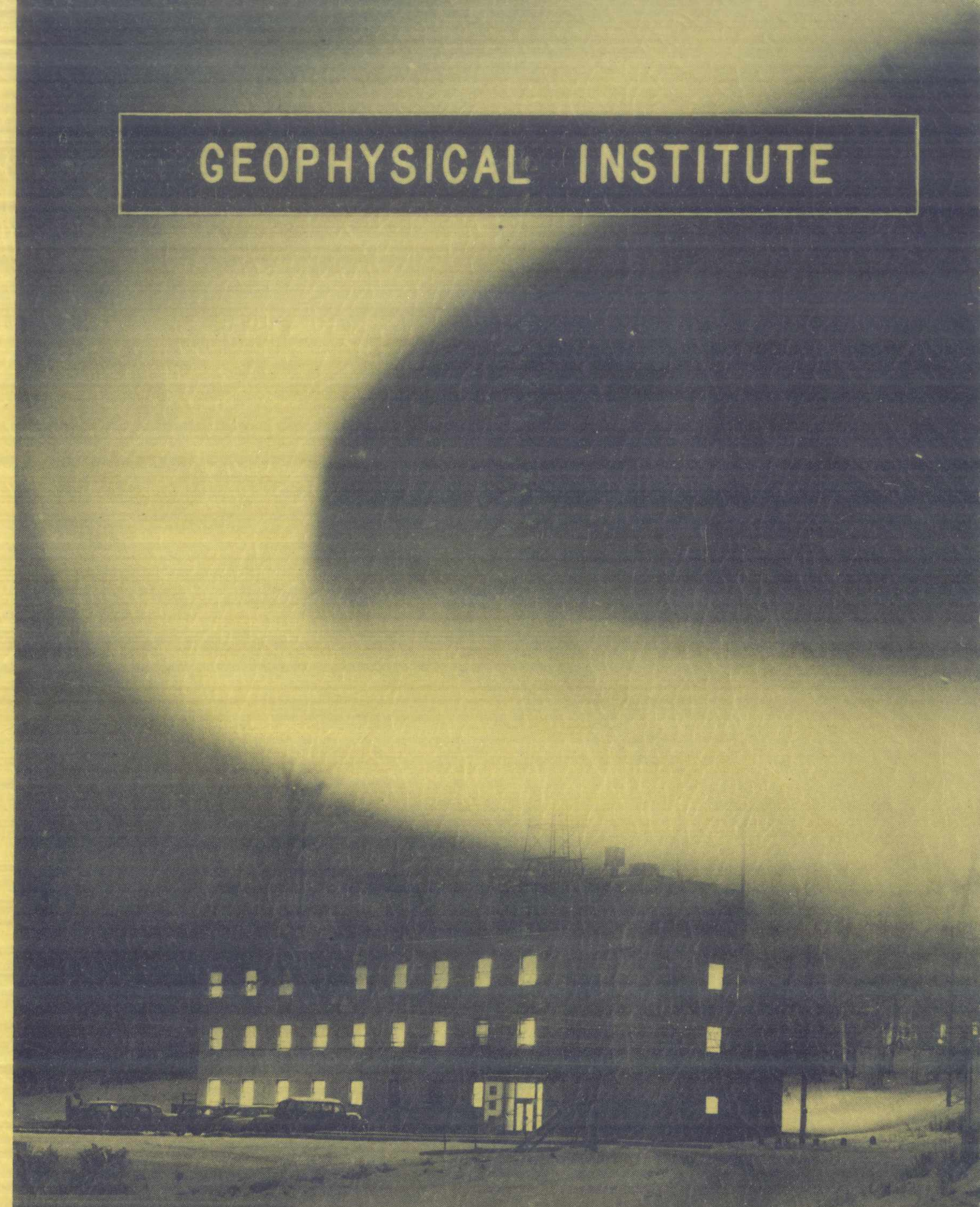
K.B. MATHER

GEOPHYSICAL INSTITUTE



UNIVERSITY OF ALASKA

COLLEGE ALASKA

Geophysical Research Report No. 2

CONSTRUCTION OF AN ALL-SKY CAMERA

by

T. N. Davis - C. T. Elvey

October 1955

EXPLANATORY NOTES

The "All-Sky" camera described in the following report is an improved model of one which has been in operation at College and Point Barrow during the past year. The report was written, however, prior to the testing of the camera under actual working conditions; consequently a few defects have been found which are as follows:

(1) The latching relay, Fig. 6, is too critical in adjustment. Since it is unnecessary when the frequency of the alternating current is sufficiently accurate for timing, we have removed it. Such type of relay can be installed as part of the timing circuit when it is necessary to employ a chronometer or clock to time the exposures.

(2) The numerical clock (electric), Fig. 8, has given trouble by sticking when all wheels are being turned at midnight. This may be due to the modification which was made in the clock by inserting a programing wheel. It would be cheaper and more reliable to use a separate 1 RPM motor to operate the programing wheel.

In the meantime a report by W. Stoffregen, "Report from Upsala Ionosphere Observatory to the Third Plenary Meeting of the CSAGI in Brussels, September, 1955, "has become available. Stoffregen describes an all-sky camera which has certain advantages over the one we are using. The spherical mirror of the all-sky camera has a central aperture, and a flat mirror folds the optical path so that the 16 mm recording camera is placed below the spherical mirror. Also, a lens of 25 mm focal length instead of 50 mm is used. This results in a much more compact camera, and we propose to use this design at least in all of the instruments which will be used in the U.S. expedition to Antarctica.

The entire all-sky camera can be placed in a plastic dome of a box or observing room. It is, of course, necessary to take precautions to protect the dome against the blowing ice particles near the ground level.

Since this report may be of assistance to others designing all-sky cameras for auroral observations during the International Geophysical Year, we have made the report rather detailed and are also including as Appendix A the prospective sketch of Stoffregen's camera, the photograph of his instrument, and copies of some photographs taken with the camera. It will be noted that

Stoffregen calibrates the angular measurements by means of lights placed on arcs over the instrument.

Appendix B is a sketch of the revision of Stoffregen's camera which we propose to construct for the U.S. Antarctic stations.

C. T. Elvey
October 20, 1955

CONSTRUCTION OF AN ALL-SKY CAMERA

T. N. Davis and C. T. Elvey

INTRODUCTION

The "All-Sky" camera herein described is an outgrowth of cameras operated in Alaska by the staff of the Geophysical Institute.[1] The principle has been of use in cloud studies and was first used by C. W. Gartlein for auroral photography. In its present form the camera is capable of recording stable or slowly moving auroral forms and is useful for synoptic mapping of auroras and detail studies. By proper scaling methods the camera gives fairly well defined mapping of aurora occurring within a circle of 500 km radius and along the lengths of arcs, i.e. geomagnetic East and West, to distances of about 1200 km. These radii are based on an estimated lower border height of 100 km with curved earth consideration.

Since the main use of the camera will be in high latitudes where severe weather conditions occur, special effort has been made to design a rugged instrument capable of withstanding high winds and low temperatures. Ease of operation under adverse weather conditions has also been a consideration. Whenever possible, use has been made of commercially available parts to reduce construction costs. An attempt has been made to simplify the construction of those parts not commercially available. The camera is designed to be built in a shop having a drill press, lathe, milling machine, welding equipment, and carpentry tools.

The recording element is a 16 mm movie camera with a 50 mm f/1.5 lens and equipped for lapse-time photography. The camera views the entire sky in a convex mirror. A number of cameras have been considered, two of which, the Bolex H-16 Leader and the Kodak K-100, appear best suited with respect to cost and adaptability. The Bolex H-16 is equipped for lapse-time photography and requires no modification. The Bolex has the disadvantage of only sixteen feet of film run per spring winding, hence, requires attention each ten hours if one picture per minute is to be taken. The Kodak K-100 must be modified for lapse photography but has forty feet of useful film run and will operate without attention for twenty-four hours at one frame per minute. Both these cameras may be solenoid driven which allows variation of exposure times with minimum effort.

An overall view of the camera is shown in Fig. 1. Fig. 2 shows the optical arrangement. Calculations made on the basis of Fig. 2

and the graph of height, angle, and distance, Fig. 3, allows the location with respect to the earth's surface of any point on the photographic image.

CONSTRUCTION OF THE CAMERA

The all-sky camera is composed of four main parts: base assembly, camera support assembly and calibration markers, control assembly, and camera housing assembly.

(1) Base Assembly: The base serves as a stable platform to carry the controls, mirror, calibration ring, and the camera support assembly. To obtain rigidity, it is constructed of a 2" x 4" framework covered with 3/4" exterior plywood. The assembly is held together with lag bolts and wood screws to enable dis-assembly for shipping. Fig. 4 gives details of assembly. (The aluminum straps to support the control housing are shown with greater detail in Fig. 10.)

Prior to their assembly the wooden base parts should be painted to prevent weathering. The top of the base is covered with flat-black paint to provide a non-reflecting surface. A leveling bubble is set into the surface to aid in installation.

(2) Control Assembly: The control housing, located in the center of the camera base, serves to house the timing circuitry and to support the mirror. The details of construction are shown in Fig. 5. The bottom and four sides of the box are 1/2" plywood, and the top is made of 1/8" aluminum. Excepting for the top, 1/2" stiff insulating material such as CELOTEX is used to line the box. The aluminum top, shown in Fig. 10, is intended to transfer heat to the mirror so that frost will not form on it.

The timing circuit, located in the control housing, includes a one revolution per minute synchronous motor driving a programing wheel (see Fig. 9). Projections on the wheel operate a microswitch, which in turn operates a latching relay in the solenoid circuit. The arrangement is such that once each motor revolution one projection on the wheel causes the relay to close the solenoid circuit which opens the shutter and advances the film. A second wheel projection again operates the relay to close the shutter. The twenty-four possible positions on the program wheel allow any exposure between 2.5 and 57.5 seconds in 2.5 seconds increments.

The timing motor also drives the wheels of a 24-hour numerical clock which is in the field of view of the camera to give a timing mark on each frame. Manually controlled day-month wheels are also provided (see Fig. 9). The timing indicators are illuminated by neon bulbs on a circuit fired by a microswitch operating from the side of the program wheel.

Inasmuch as this timing system is dependent upon line frequency which may not always be stable, provision is made for also photographing a pocket watch. Comparison of the times given by the watch and the numerical clock will allow quantitative detection of unstable frequency and the resultant timing errors. In the event that very accurate timing is required, or if two or more cameras are to be synchronized, an input is provided for external timing.

Heating of the assembly is accomplished by two heating circuits. One circuit providing 40 to 50 watts is controlled by a thermostat. When this circuit is unable to maintain the temperature, two additional heaters with manual control may be used in addition to the thermostatically controlled heaters. This should provide sufficient heat even under the most severe conditions. The above circuitry is shown in Fig. 6, and the main mounting bracket for placement of the various components in the assembly is shown in Fig. 8.

The openings in the cover plate may be covered either with glass or Lucite. This cover is readily removed for access to the control system.

By removing the power input cable and the connection to the camera assembly, the entire control housing may be lifted out of the base for servicing.

(3) Support Assembly and Calibration Markers: The four support legs are aligned to give geomagnetic directions. Short marker bars on the meridian legs indicate degrees of latitude (see Fig. 11). The calibration ring, also shown in Fig. 11, is placed to mark an angle of 80° from the zenith. The ring supports, along with the support legs, also give horizontal calibration each 30°. On the film the various calibration markings appear as unexposed areas; hence, the calibration marks show only when there is sufficient light from the sky to cause some exposure.

The support legs shown in Fig. 12 are bolted into the base, and their upper ends fit into the steel camera yoke, Fig. 13. The yoke is aligned with the main length along the east-west axis.

(4) Camera Assembly: The camera assembly consists of the 16 mm camera with its mountings, solenoid, heating system, and the insulated housing. The assembly fits into the camera yoke and may be lifted out vertically. The control cable is contained in the east support leg where it passes through the base cover and framework to the control housing.

The housing construction is similar to that of the control housing except that no insulation is used on the south side where the camera is mounted. Position in the yoke is controlled by aluminum angle plates fastened to the sides of the box (see Fig. 14).

Two 300 ohm 50 watt resistors are placed with their thermostat control near the bottom of the housing. Attached to the south side of the housing is the camera base-plate which has adjustable positioning. The adjustable camera ways are attached to the camera base plate. The camera support-plate slides into the ways from above, the final resting position being governed by a slotted stop plate at the bottom of the ways. This assembly is shown in Fig. 5.

Fig. 16 shows the mounts required to connect the solenoid and camera. Assembled views are shown in Fig. 17 and 18. Fig. 18 also shows a part of the modifications which must be made to the Kodak K-100. The chief modification is to the actuating lever which normally allows the shutter to rotate 360° each exposure. The stop at the end of this arm may be heated and bent so that it interrupts the shutter motion in the open position. Upon release of the actuating arm the shutter completes its 360° cycle. The operating trigger is replaced by a shaft and bearing assembly which connects to the solenoid as shown in Fig. 18.

(5) Final Assembly: It is important that the optical axis of the camera and the center of curvature of the mirror be on the same line to avoid distortions. This adjustment can be made with the camera base plate assembly.

Proper positioning of the latitude markers can be determined from Fig. 3. The accuracy of the markers and the calibration ring depend upon the base and mirror support being level.

USE OF THE CAMERA

During the past year at College and Pt. Barrow, Alaska, an exposure time of 55 seconds has been used with Linograph Panchramatic film and normal D-19 (Eastman Kodak) development. The use of new films and development techniques may reduce the necessary exposure time.

The reduction of data may be made in several ways: one, that of making synoptic maps of auroral forms, is useful for detail studies of development and motion. To do this the film is projected on a reader to enable the positions of lower borders to be located with respect to some coordinate system. An alidade for this purpose is shown in Fig. 20 assuming 100 km as height of lower border. It gives distance and azimuth from the observing point which allows the aurora shown in Fig. 19 (taken at College with the previous camera) to be plotted on a map as in Fig. 21. Such a device can be constructed from the information given in Figs. 2 and 3.

An index of auroral activity may be obtained from densitometric measurements of the photographs of the entire sky, or any portion of it. A comparison of the auroral intensity (relative) derived by this method with that measured with a photoelectric photometer integrating the light of 3914A over the entire sky, is shown in Fig. 22. Also shown in Fig. 22 are measurements of the zenith absorption by the ionosphere of galactic radio noise showing a strong correlation between absorption and auroral intensity. This photographic index of auroral activity has merit as has been shown by several investigators, and it is urged that all films made with the all-sky camera during the International Geophysical Year be calibrated with a sensitometer.

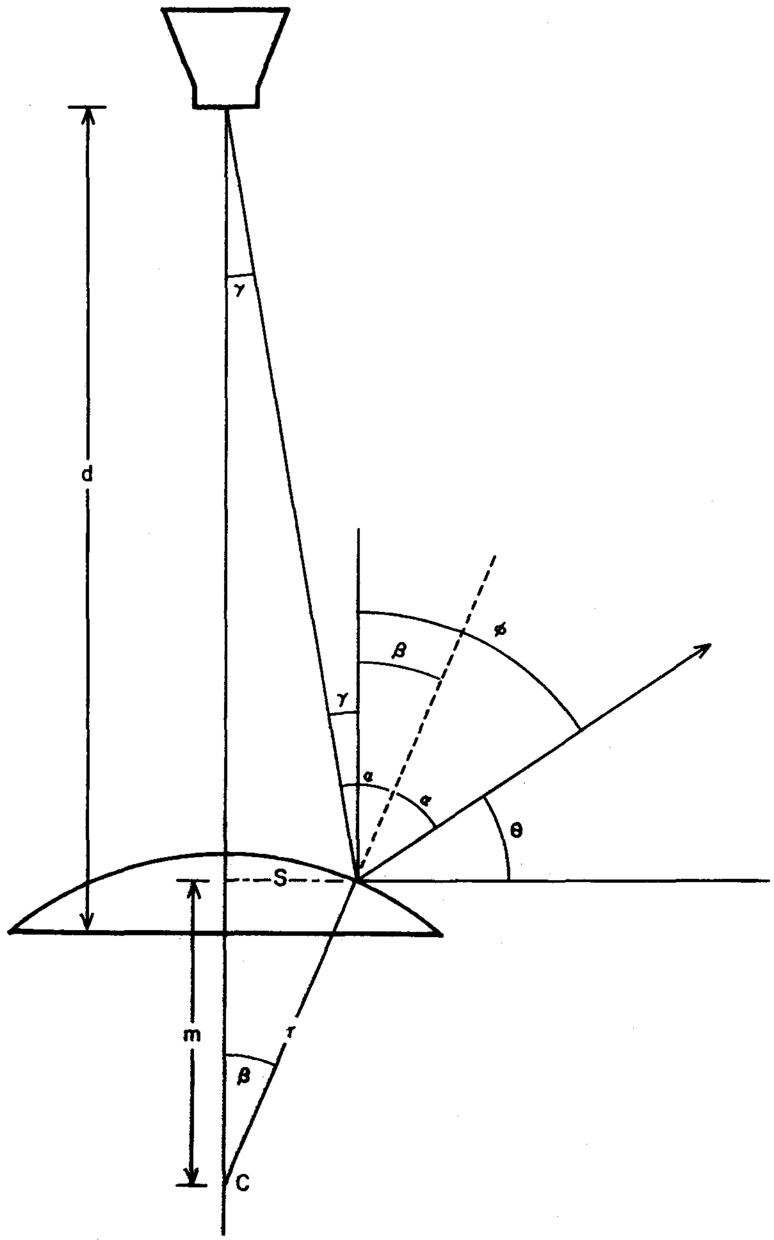
For statistical purposes a method is being tested whereby the information given by the film is punched into I. B. M. cards. For this purpose that portion of the sky along the geomagnetic meridian is divided into sections representing one degree of latitude each for individual description. Each sector is alloted certain columns on the card where the aurora is described. A classification of four forms has been used: arcs, being well-defined forms paralleling geomagnetic latitude; broken forms, those well defined forms without particular shape; small areas of aurora lacking definition, being termed as diffuse surfaces; and veils, large areas lacking definition. Rayed forms are not well defined on the photographs owing to the long exposures. Future reduction of exposure times may allow more forms to be defined. The method of punching the presence and brightness of these forms is illustrated in Fig. 23. In addition to this information, space is allowed for the recording of unusual configurations such as 180° turns in bands. A number of columns are reserved for observational information such as camera location, timing, and general sky condition. In the past, the information from each fifteenth frame has been recorded on the cards. The data recorded in this form is convenient for use in statistical studies of various sorts, which may be done entirely by machine methods. Devices are available to enable the sorting and counting of the cards according to any punch or series of punches, or the data may be printed by machine in tabular form.

The design of the camera in its present form has heavily depended upon the experience of those persons concerned with the construction and operation of the cameras at College and Pt. Barrow. Special thanks are due Norman K. Sanders who aided materially in the design and made many of the drawings and to Carole Smith who helped in preparation of the report.

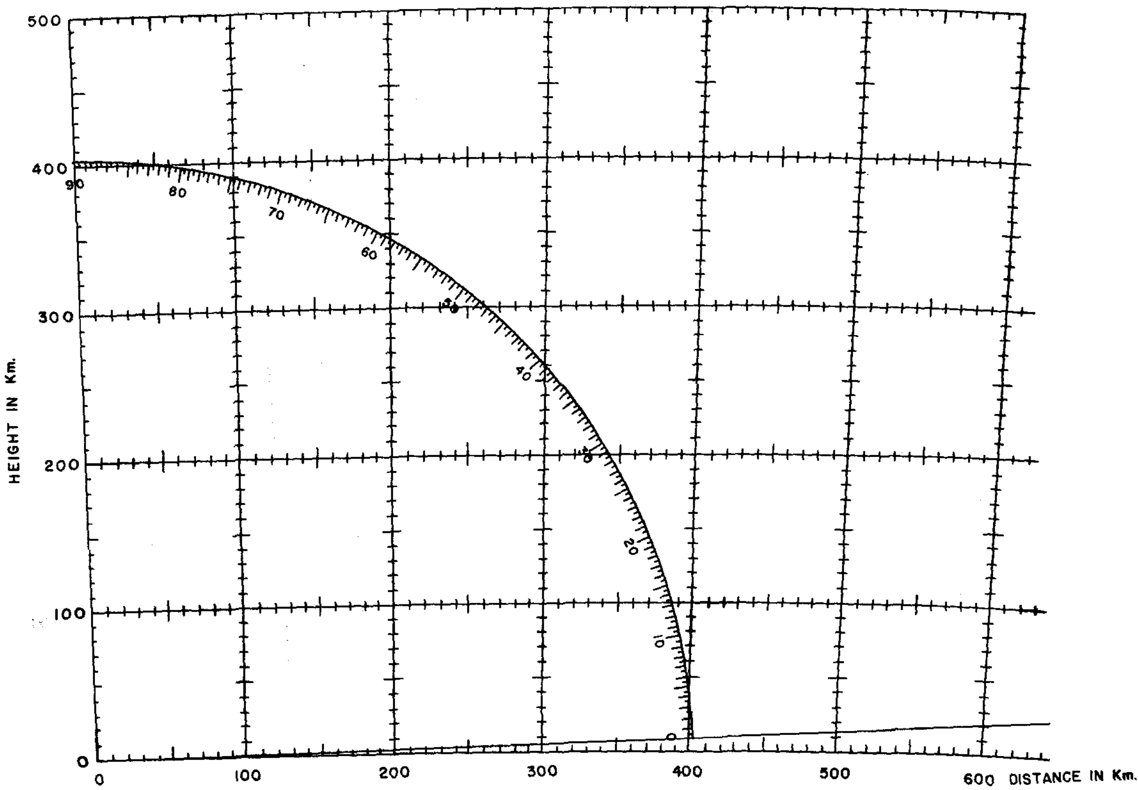
REFERENCE

1. Elvey, C. T., "Auroral Observations With An All-Sky Camera Geophysical Institute of the University of Alaska. (June, 1955)

ALL-SKY CAMERA SETUP
FIG. 1

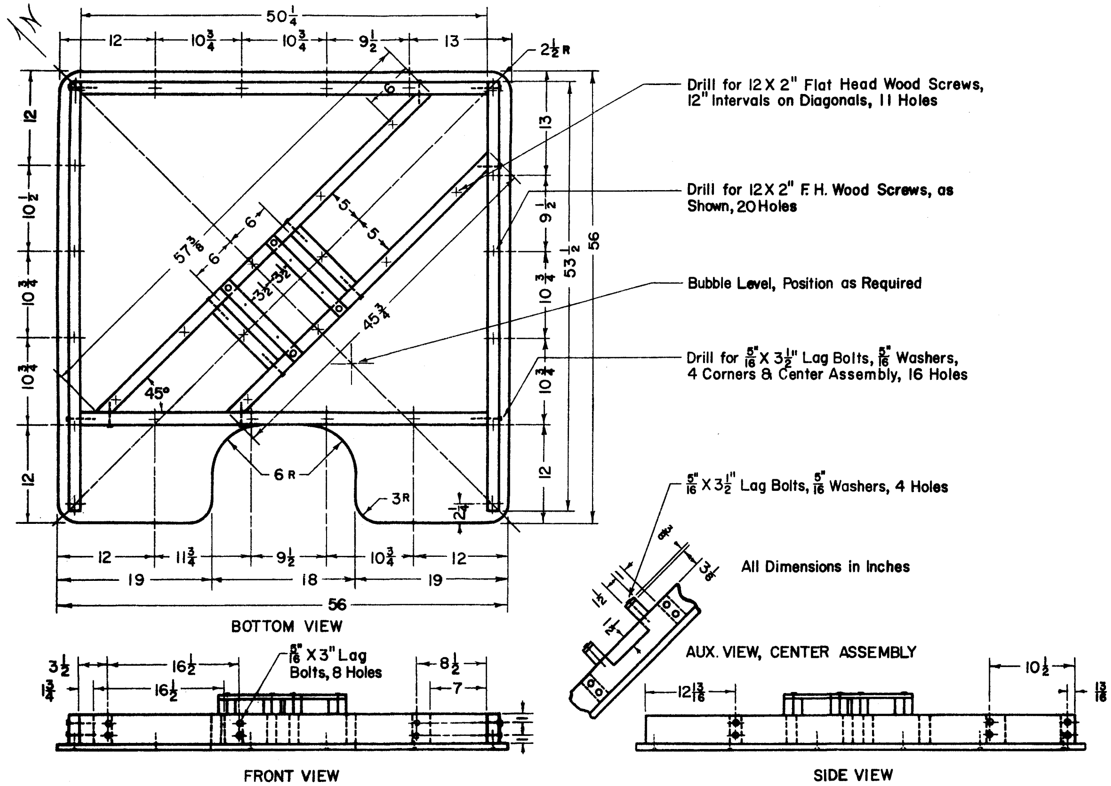


OPTICAL DIAGRAM OF THE ALL-SKY CAMERA
FIG. 2



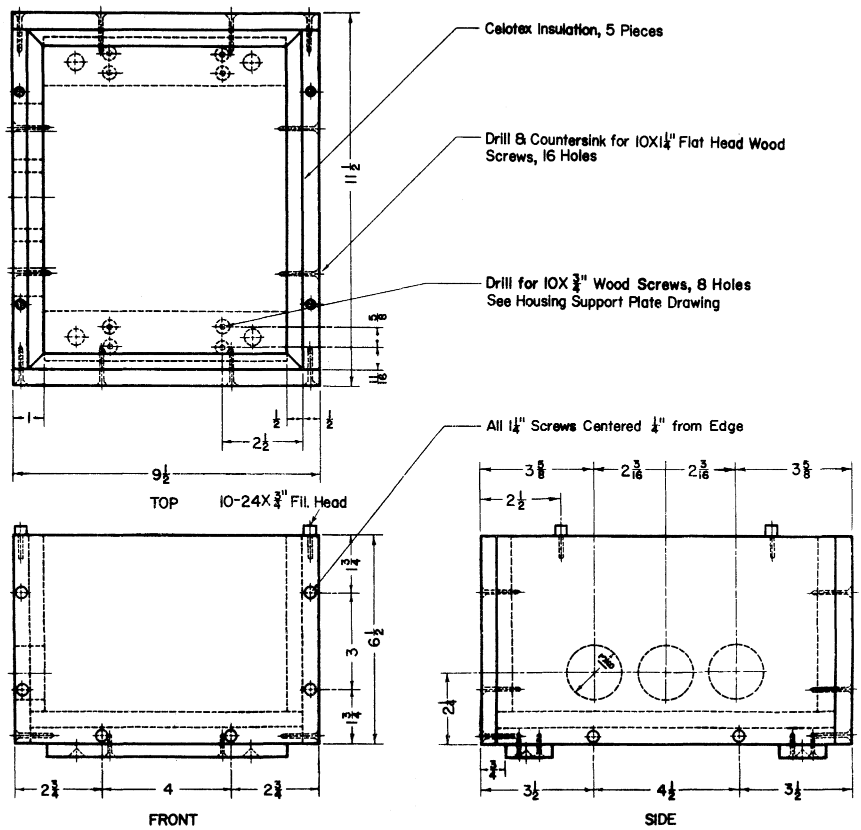
HEIGHT AS A FUNCTION OF ANGLE AND DISTANCE

FIG. 3

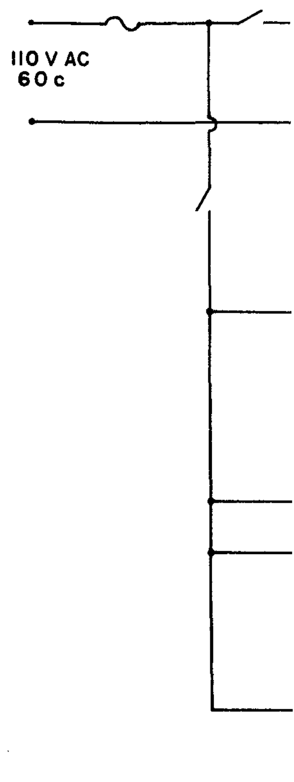


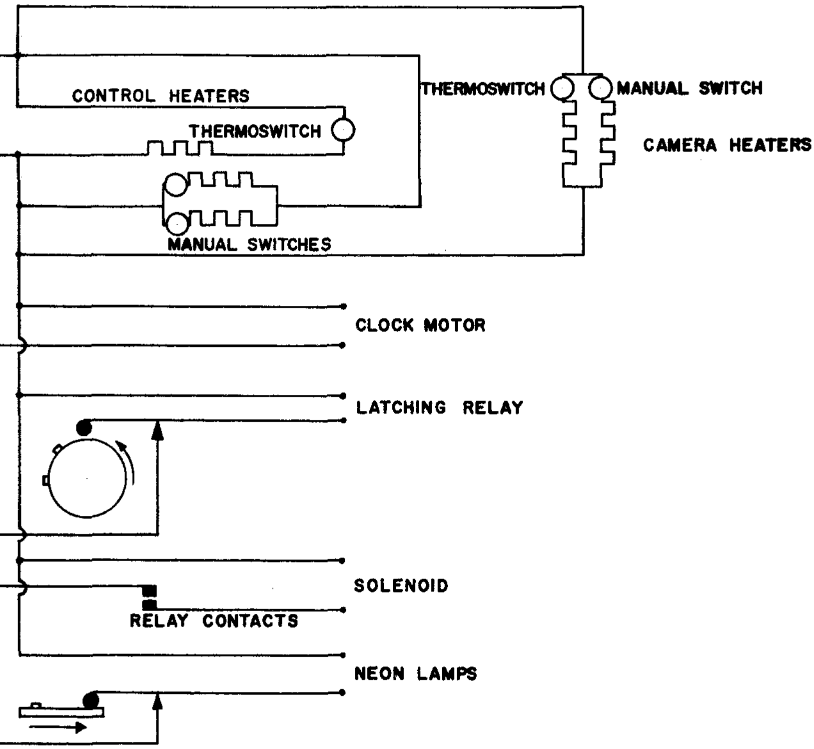
ALL SKY CAMERA BASE

FIG. 4

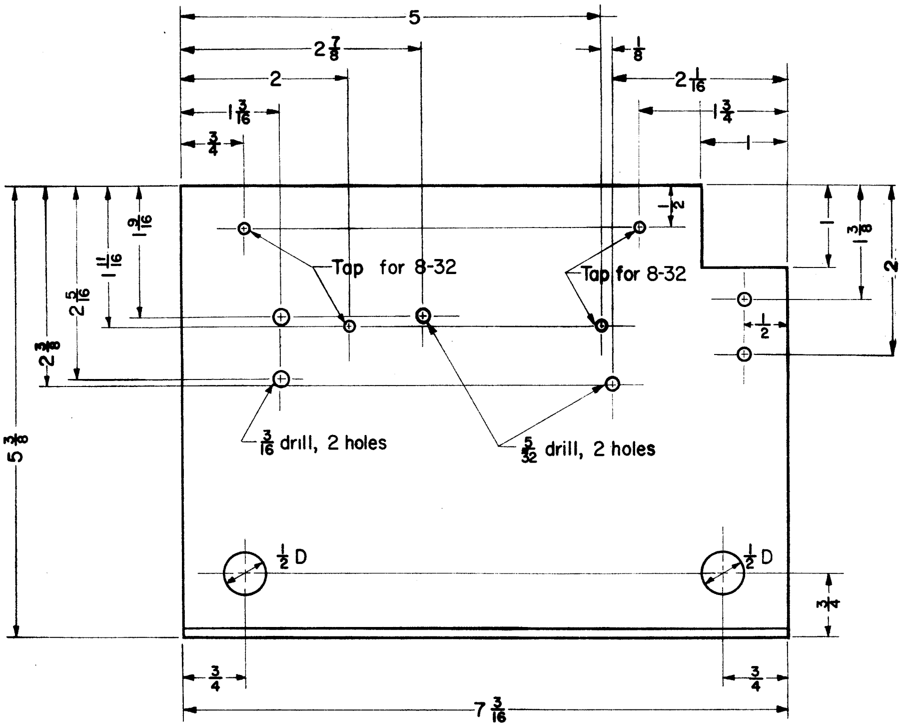


CONTROL HOUSING
FIG. 5


110 V AC
60 c



SCHEMATIC CIRCUIT DIAGRAM
FIG. 6



CONTROL MOUNT

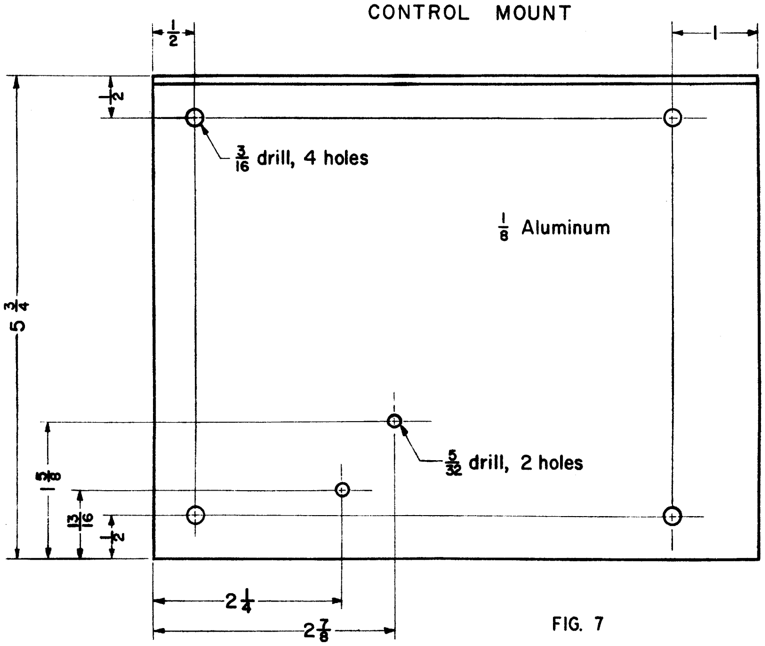
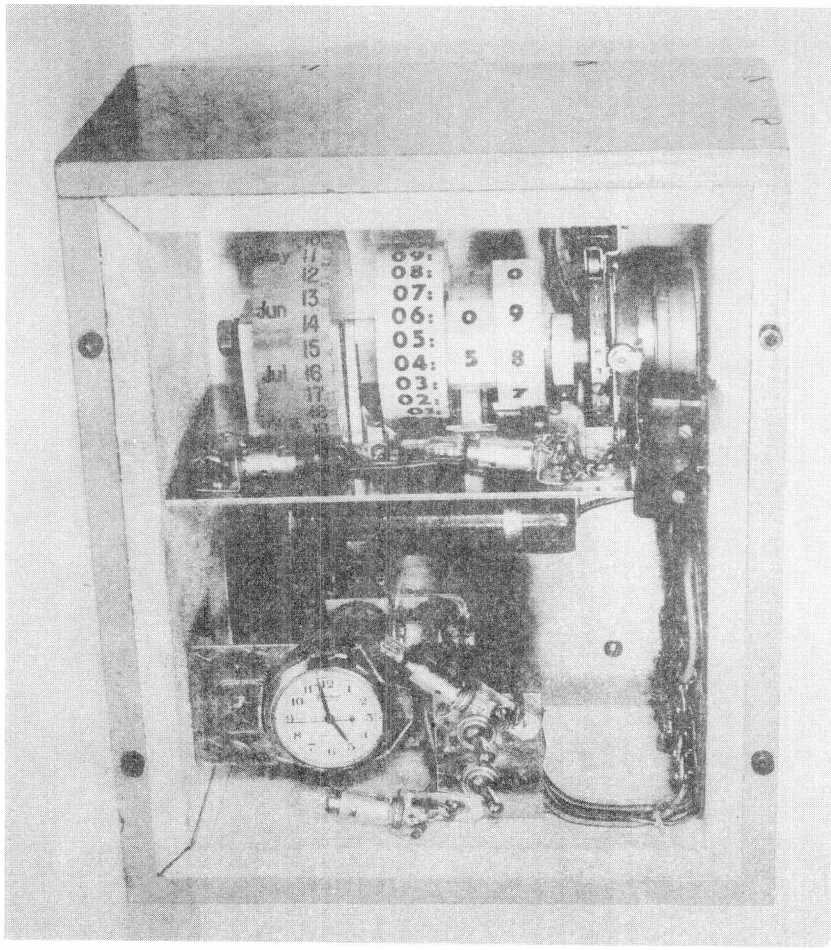
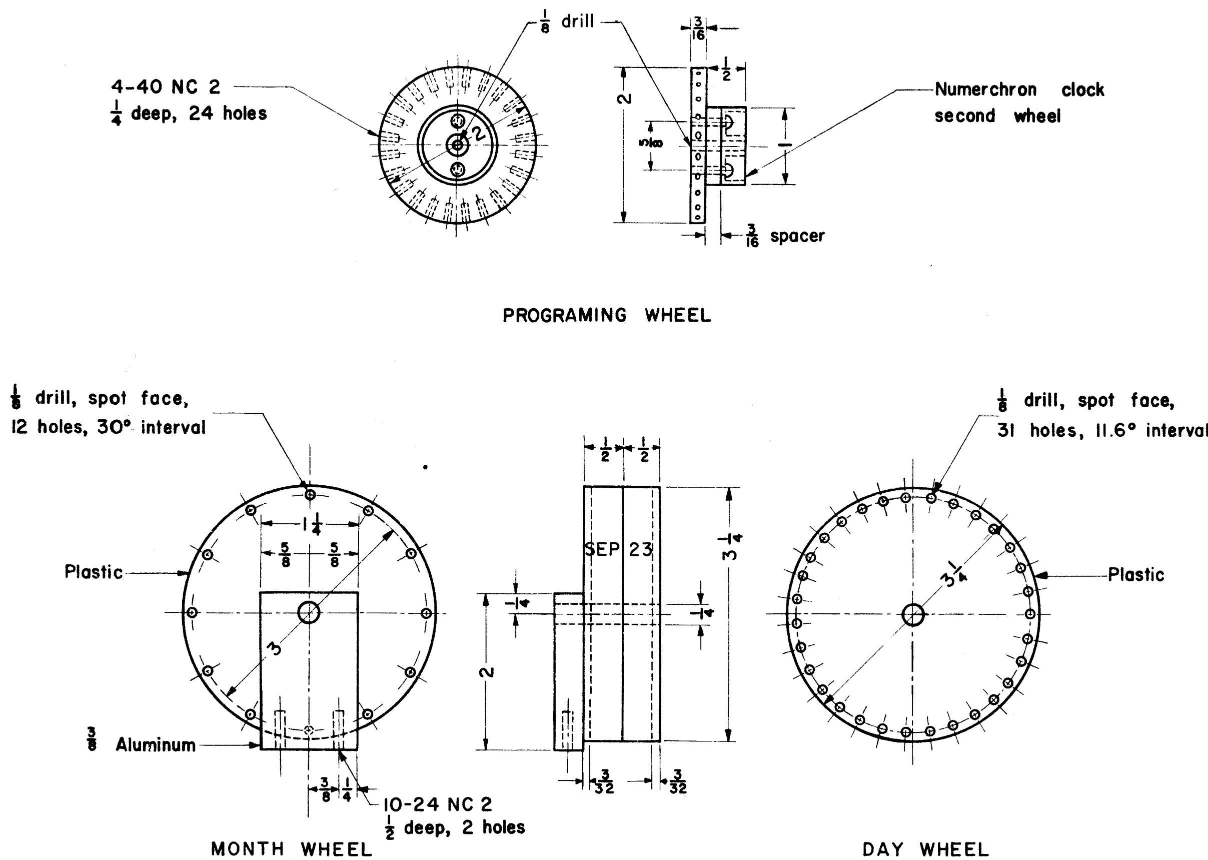


FIG. 7

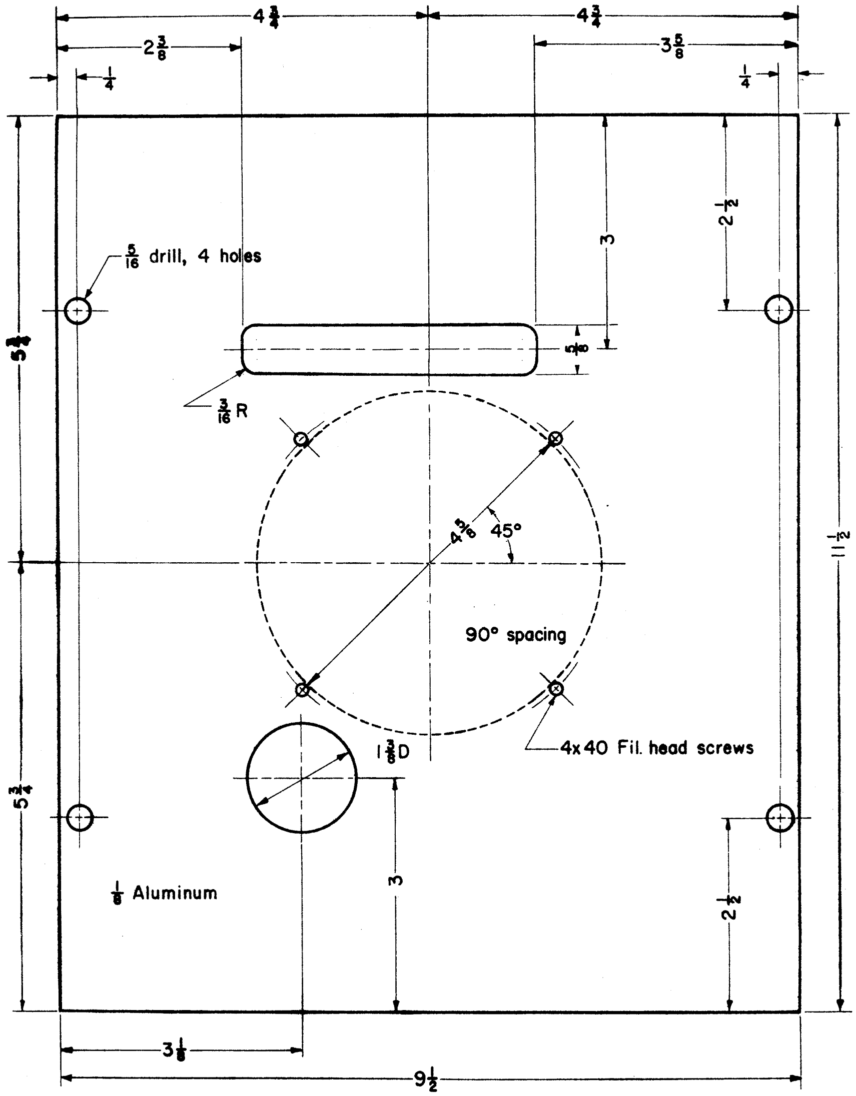


CONTROL HOUSING
FIG. 8

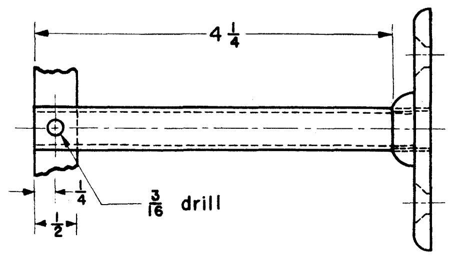


1/8 drill
4-40 NC 2
1/4 deep, 24 holes
Numerchron clock second wheel
3/16 spacer
PROGRAMING WHEEL
1/8 drill, spot face,
12 holes, 30° interval
Plastic
3/8 Aluminum
10-24 NC 2
1/2 deep, 2 holes
SEP 23
MONTH WHEEL
1/8 drill, spot face,
31 holes, 11.6° interval
Plastic
DAY WHEEL

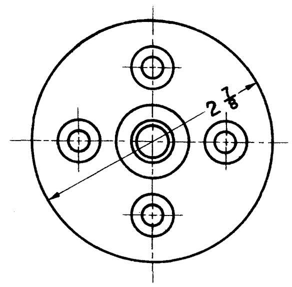
FIG. 9



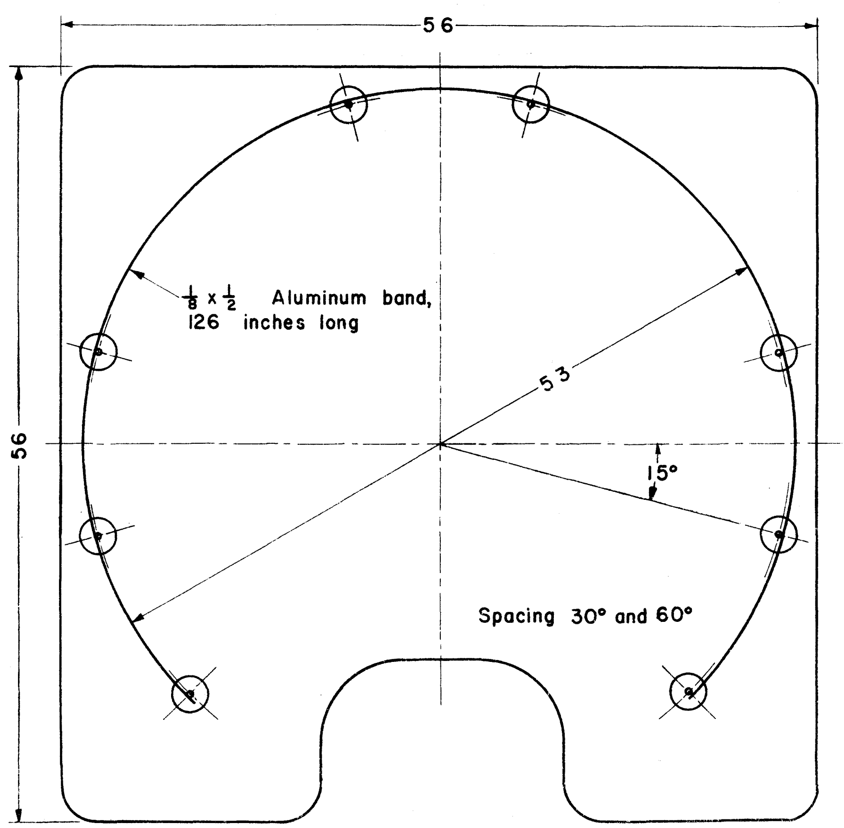
MIRROR SUPPORT
FIG. 10



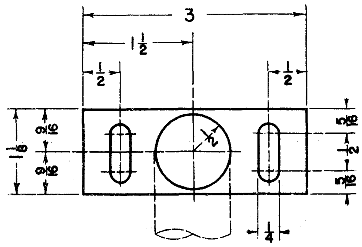
$\frac{1}{2} \times 4\frac{1}{2}$ pipe



Standard $\frac{1}{2}$ flange



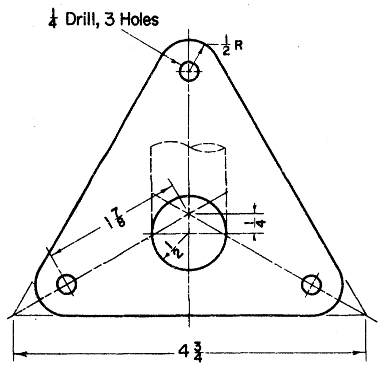
CALIBRATION RING
FIG. 11



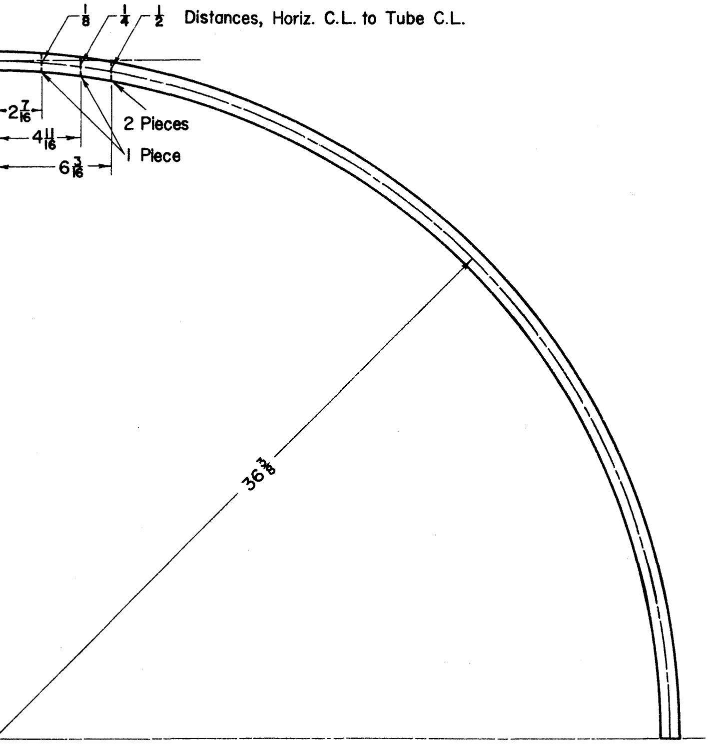
TOP PLATE

3/16 Steel, Both Pieces

Weld Tubing in Positions Shown

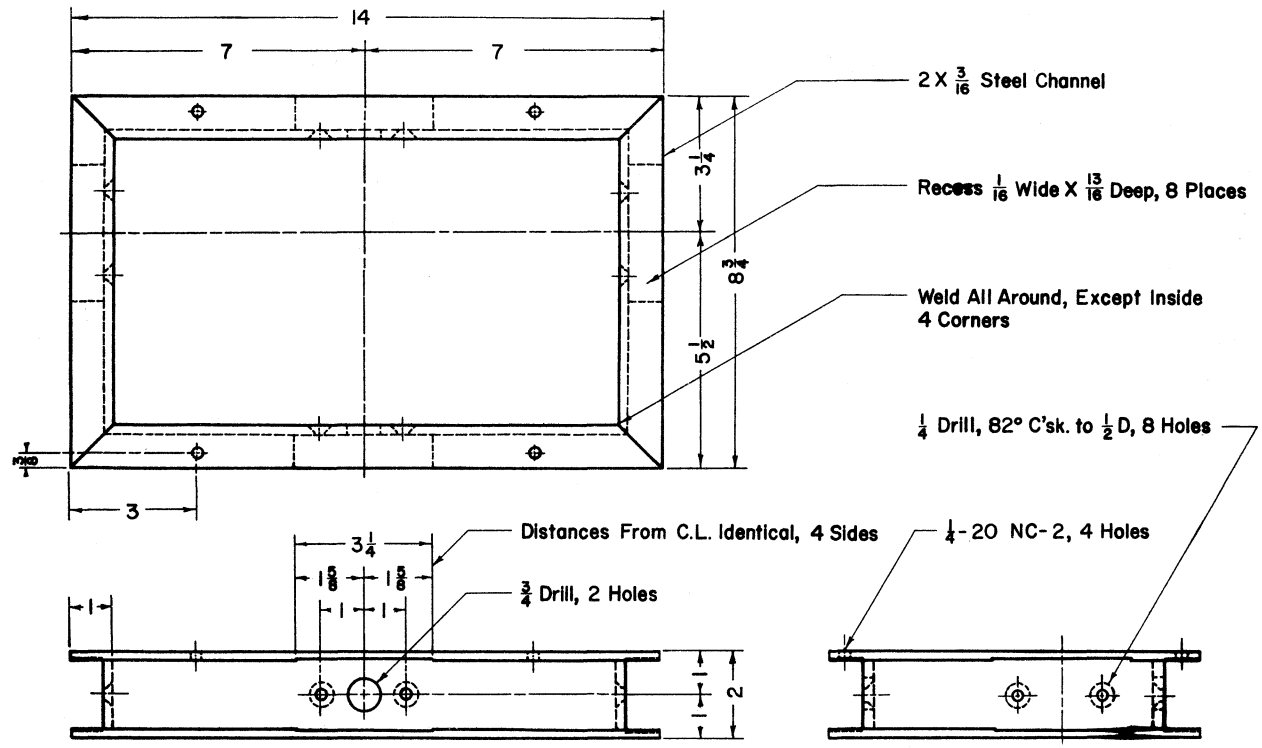


BOTTOM PLATE



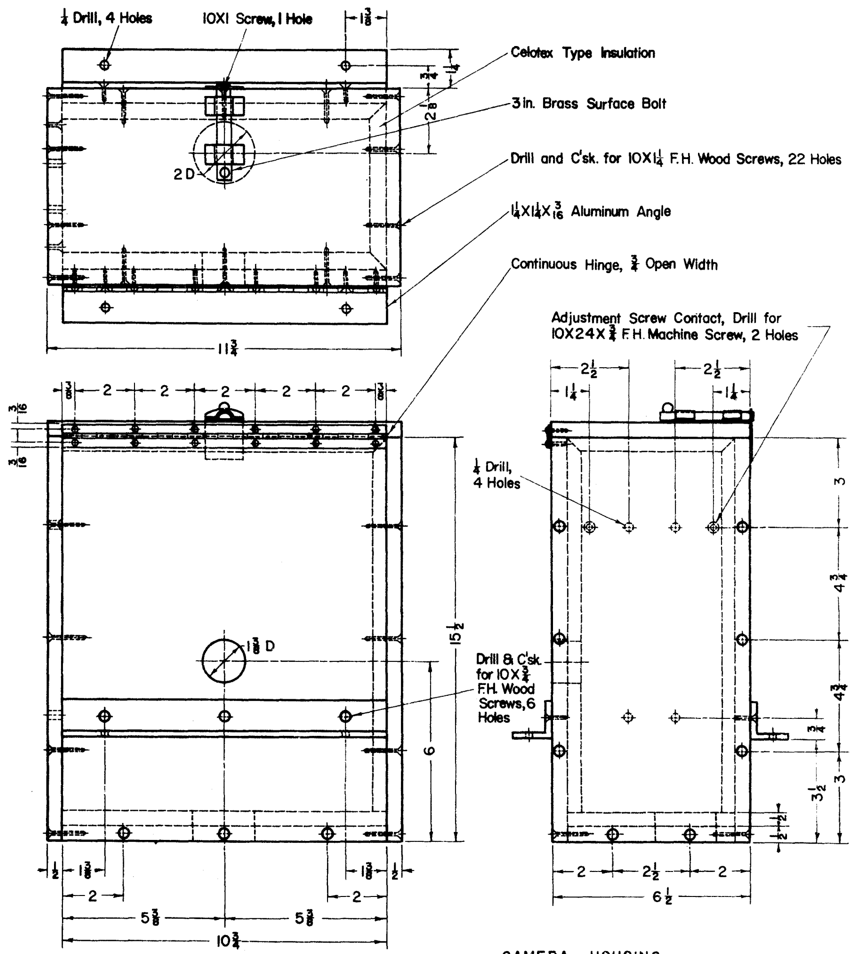
CAMERA SUPPORT LEGS

FIG. 12



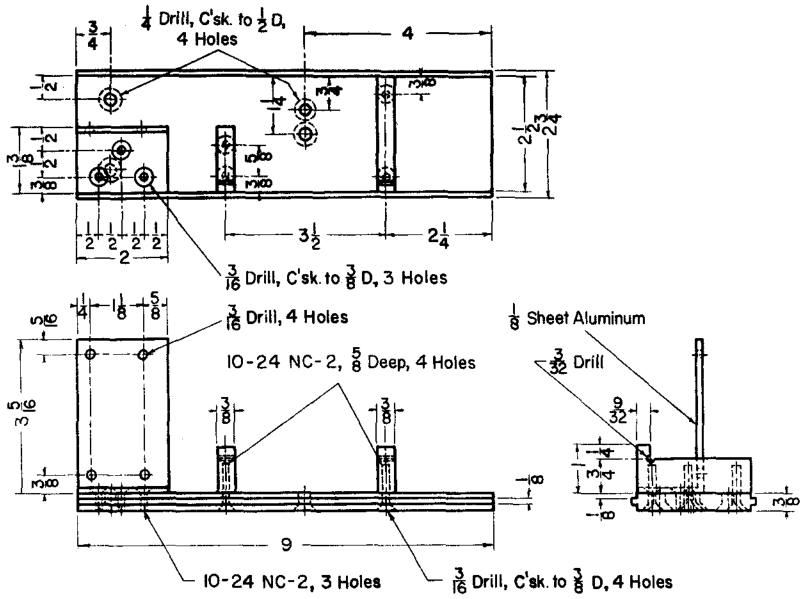
CAMERA HOUSING YOKE

FIG. 13

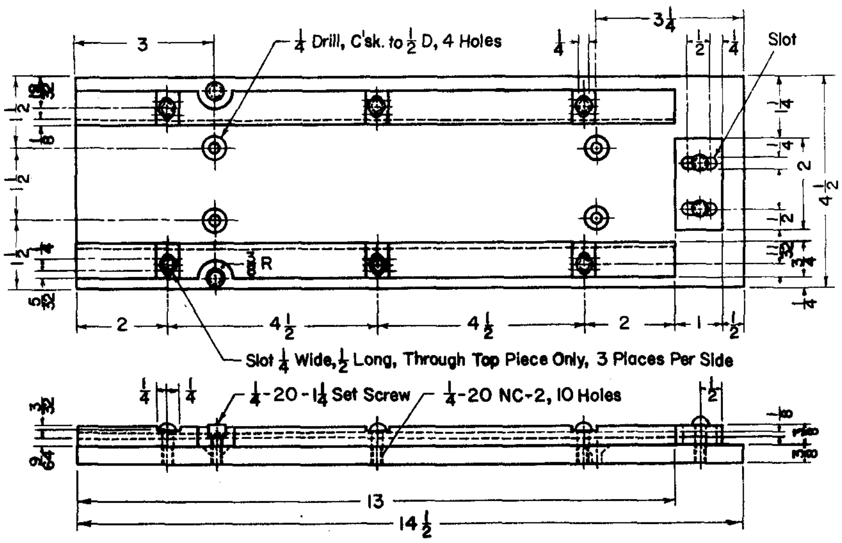


CAMERA HOUSING

FIG. 14

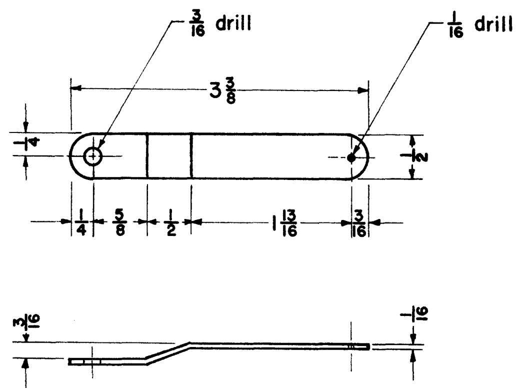


BOLEX CAMERA AND SOLENOID MOUNT

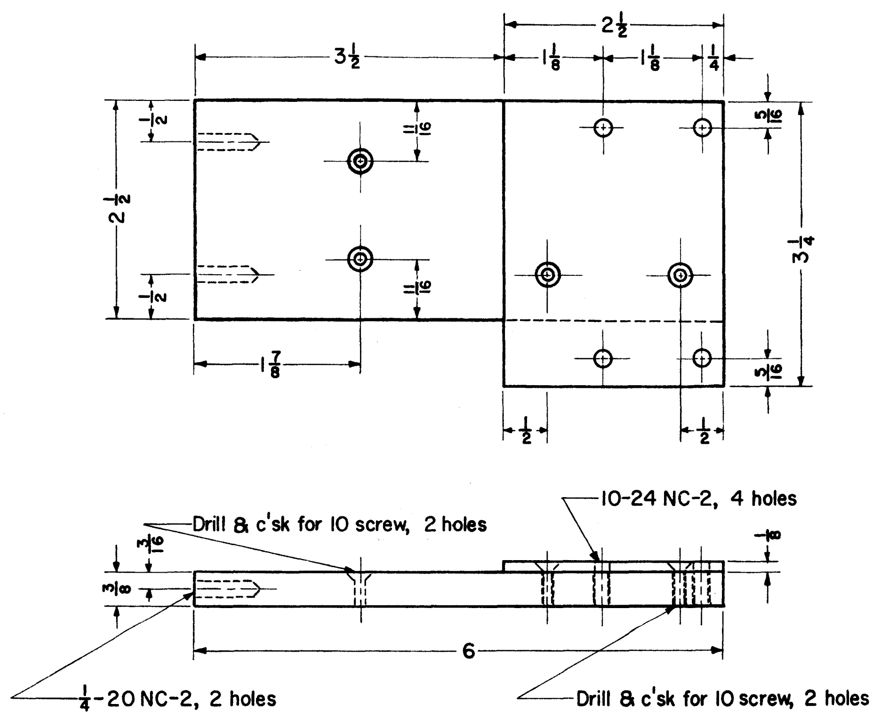


CAMERA BASE PLATE ASSEMBLY

FIG. 15

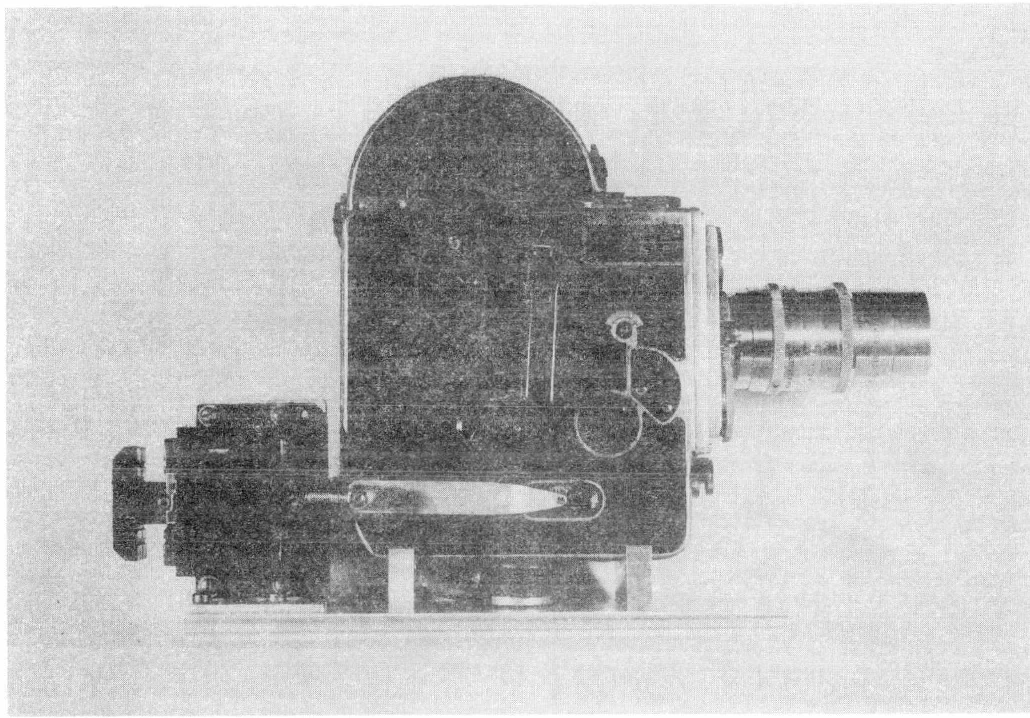


BOLEX ACTUATING ARM

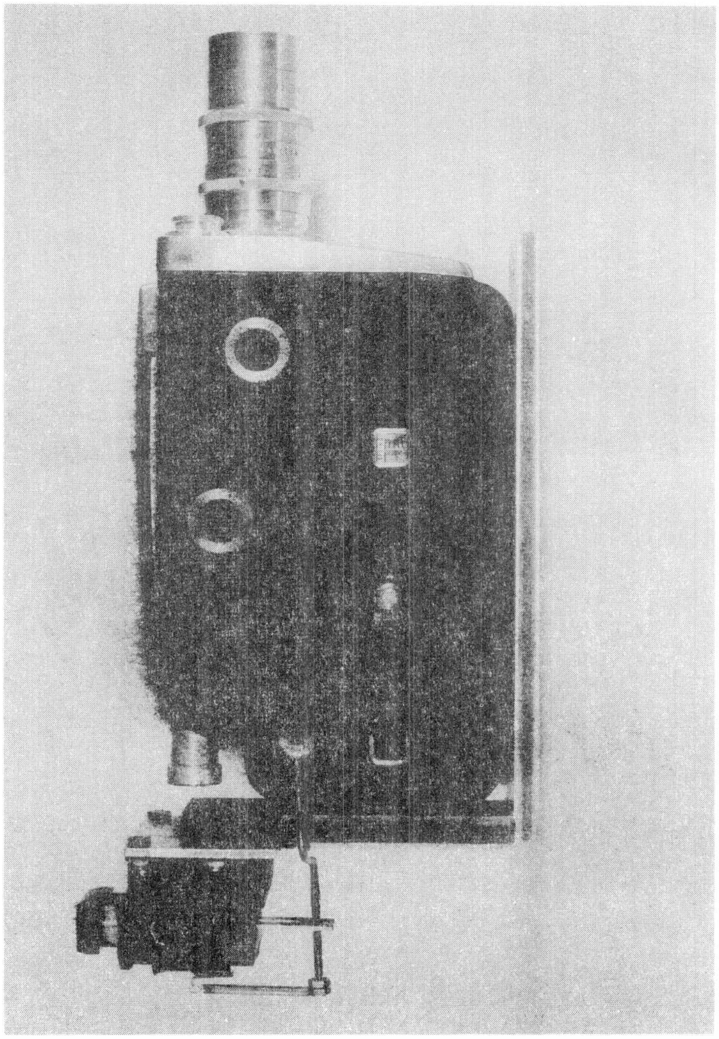


KODAK SOLENOID SUPPORT

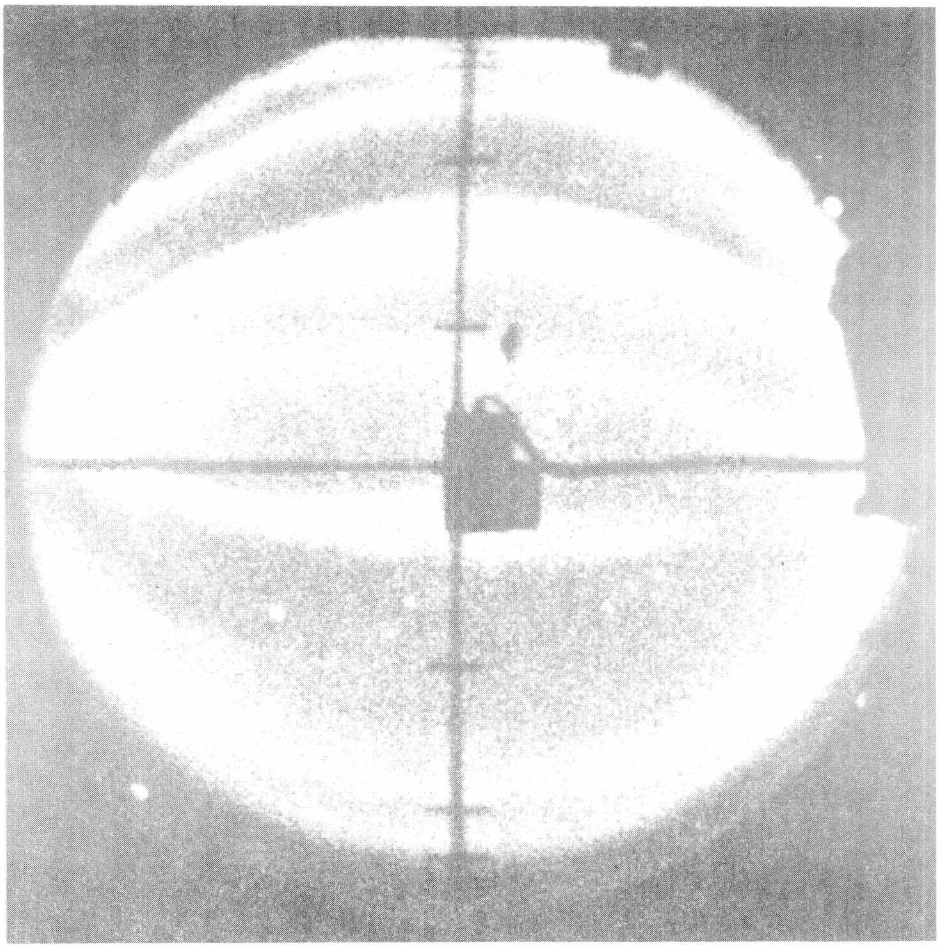
FIG. [illegible]



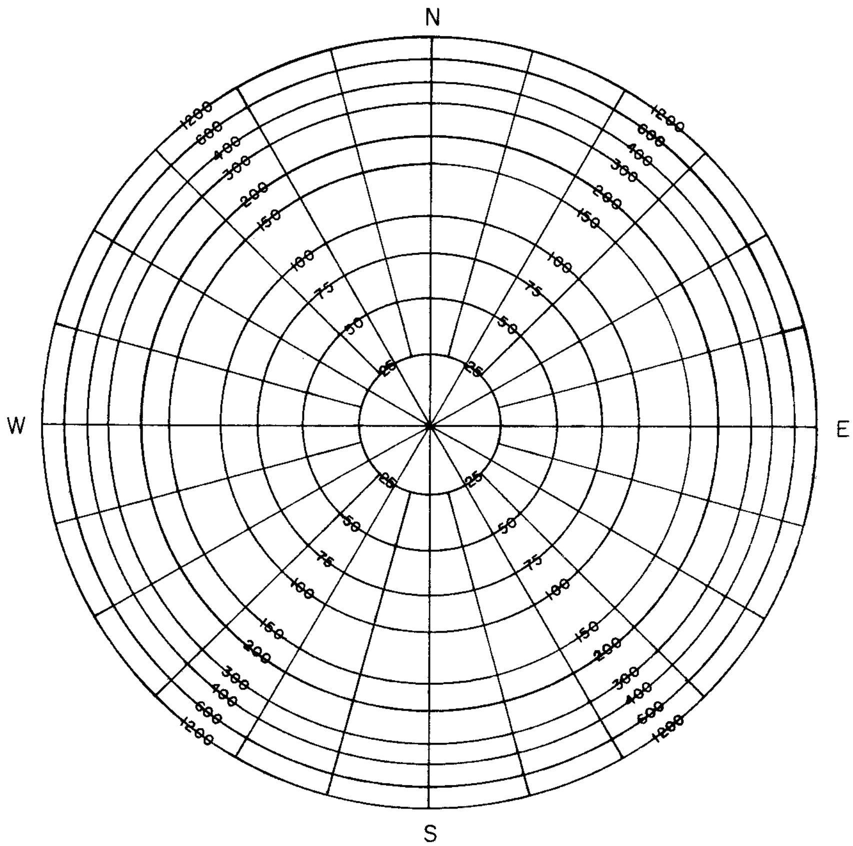
BOLEX CAMERA
FIG. 17



K-100
FIG. 18

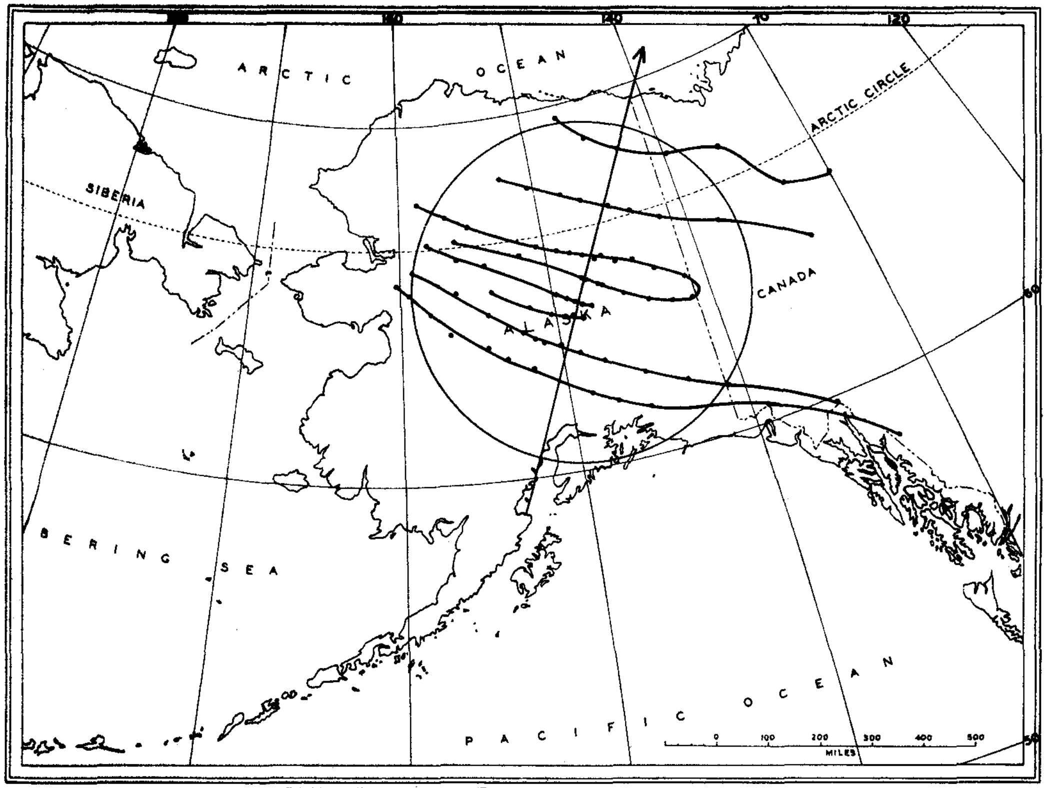


AURORAL ARCS. 2134 A.S.T. SEPT. 30, 1954
FIG. 19



AZIMUTH-DISTANCE ALIDADE

FIG. 20



DISTRIBUTION OF AURORAS OVER ALASKA
AT 21:34 A.S.T. SEPT. 30, 1954
FIG. 21

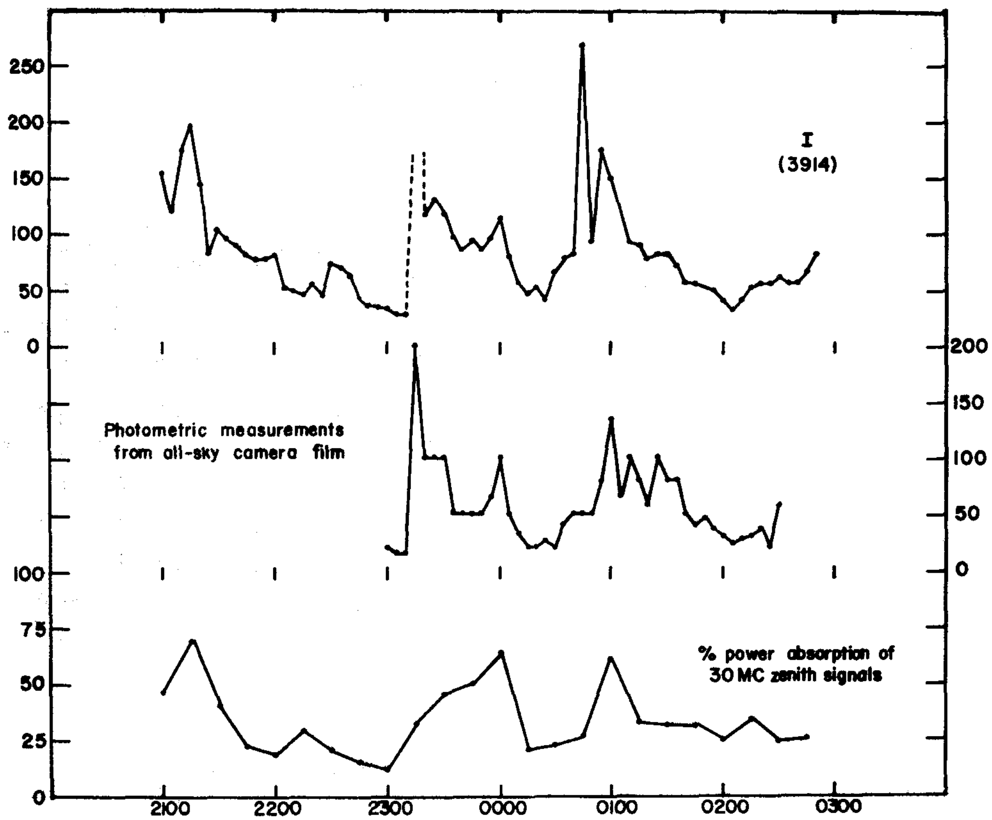


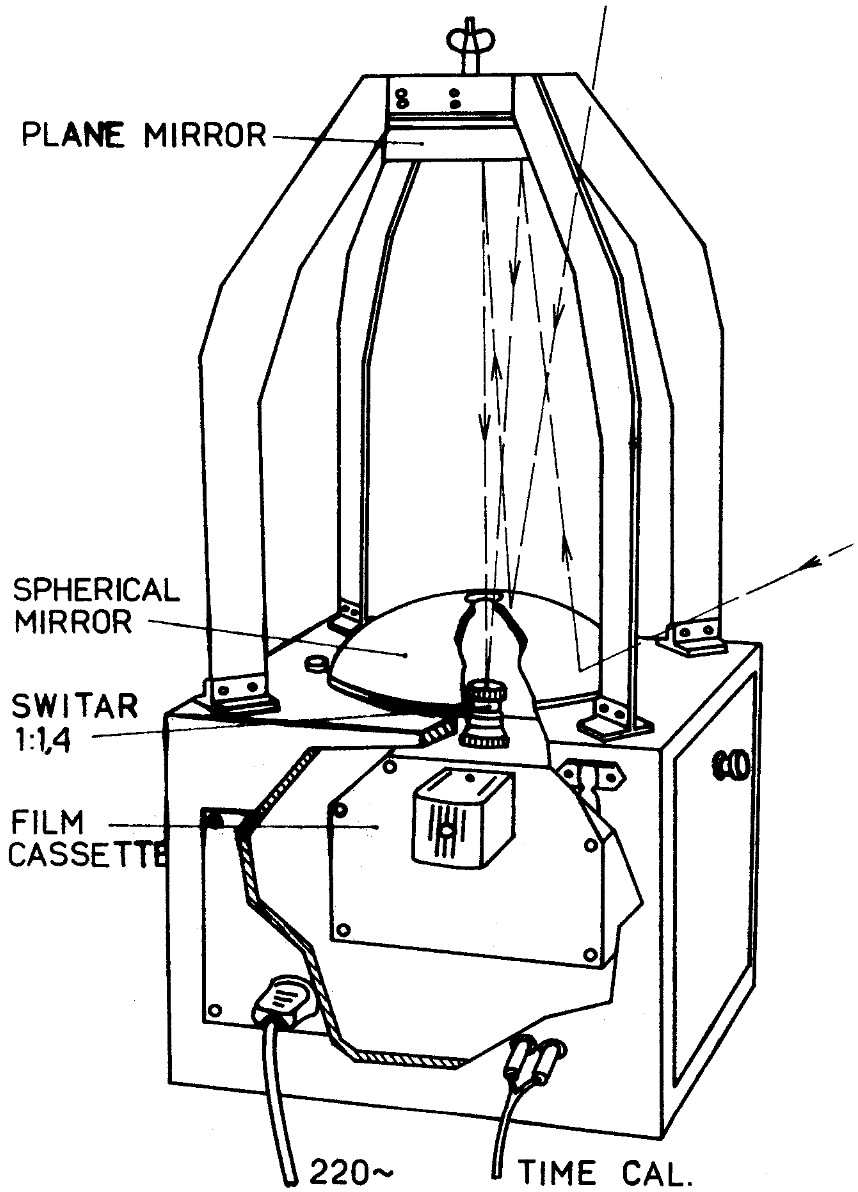
FIG. 22 COMPARISONS FOR MARCH 30/31, 1955

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	
	STATION	OPERATOR	YEAR		MONTH	DATE		HOUR		MINUTE		SKY CONDITION	MOTION	SEQ. →		SPECIAL FORMS		LN	N4	N3	N2	N1		ZENITH			S1		S2	S3	S4	LS	
R					DEC					ALL HOUR		AUR					N3	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	R
X	20	20			NOV												N2	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	X
0	10	10		0	OCT	0	0	0	0	0	0	NO AUR	0				N1	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	0
1	1	1	1	1	JAN	1	1	1	1	1	1		N SLOW	A	A		Z	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	1
2	2	2	2	2	FEB	2	2	2	2	2	2	T	N FAST	BF	BF		S1	BF	BF	BF	BF	BF	BF	BF	BF	BF	BF	BF	BF	BF	BF	BF	2
3	3	3	3	3	MAR	3	3		3	3	3	M	S SLOW	DS	DS		S2	DS	DS	DS	DS	DS	DS	DS	DS	DS	DS	DS	DS	DS	DS	DS	3
4	4	4	4	4	APR	DATE CHANGES AT MIDNIGHT	4		4	4	4	T+M	S FAST	V	V		S3	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	4
5	5	5	5	5	MAY		5		5	5	5	INF BY ↓	E SLOW				E1																5
6	6	6	6	6	JUN		6	MIDNIGHT IS 0000	6	00	6	T	E FAST				E2	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	6
7	7	7	7	7	JUL		7		7	15	7	M	W SLOW				W1	O	O	O	O	O		O			O		O	O	O	O	7
8	8	8	8	8	AUG		8		8	30	8	T+M	W FAST				W2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	8
9	9	9	9	9	SEP		9		9	45	9		RAND																				9

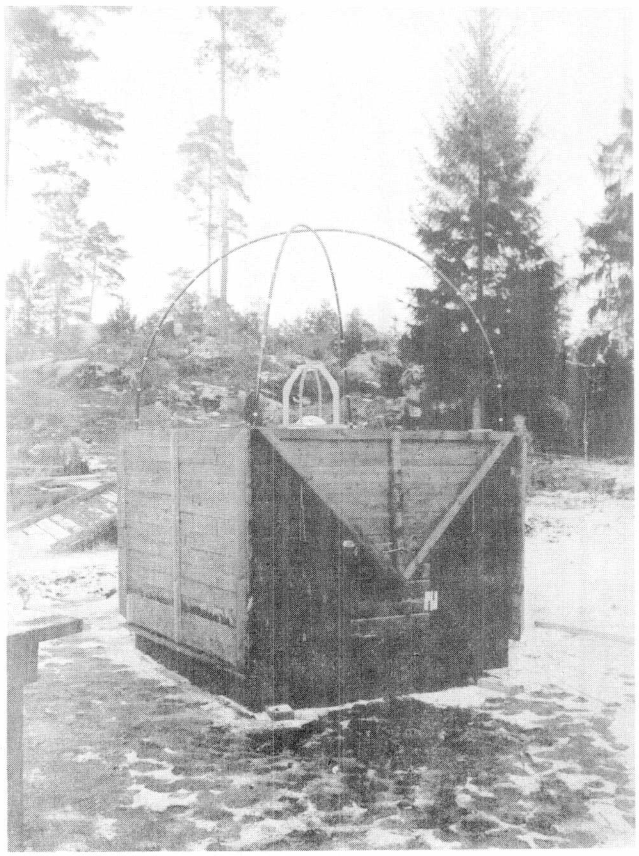
IBM PUNCHING CODE FOR ALL-SKY FILM
FIG. 23

APPENDIX A

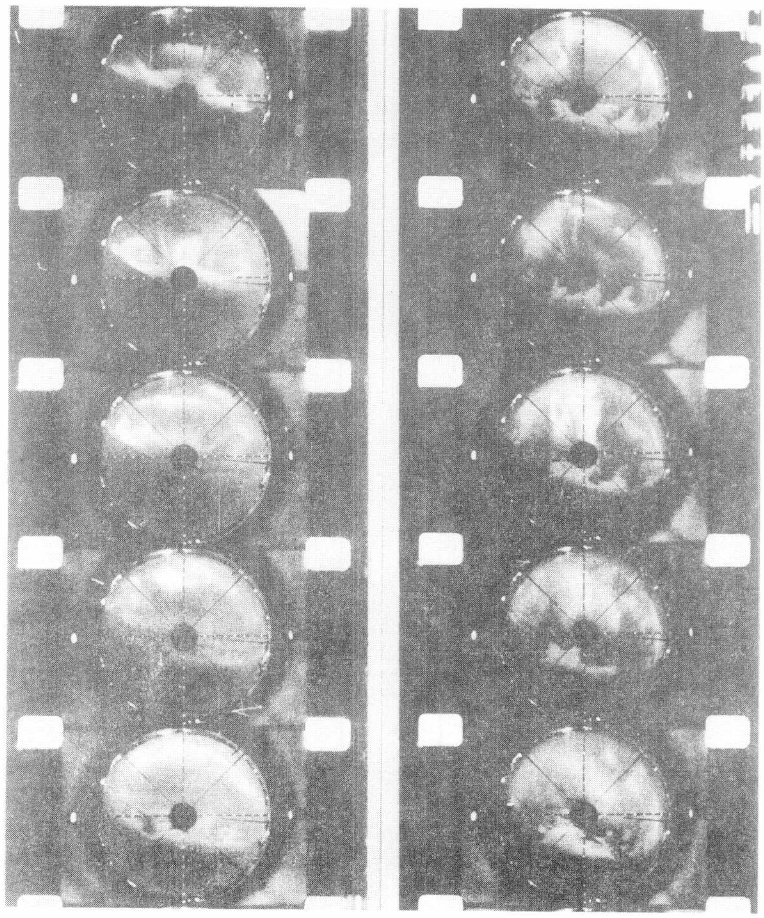
STOFFREGEN'S CAMERA



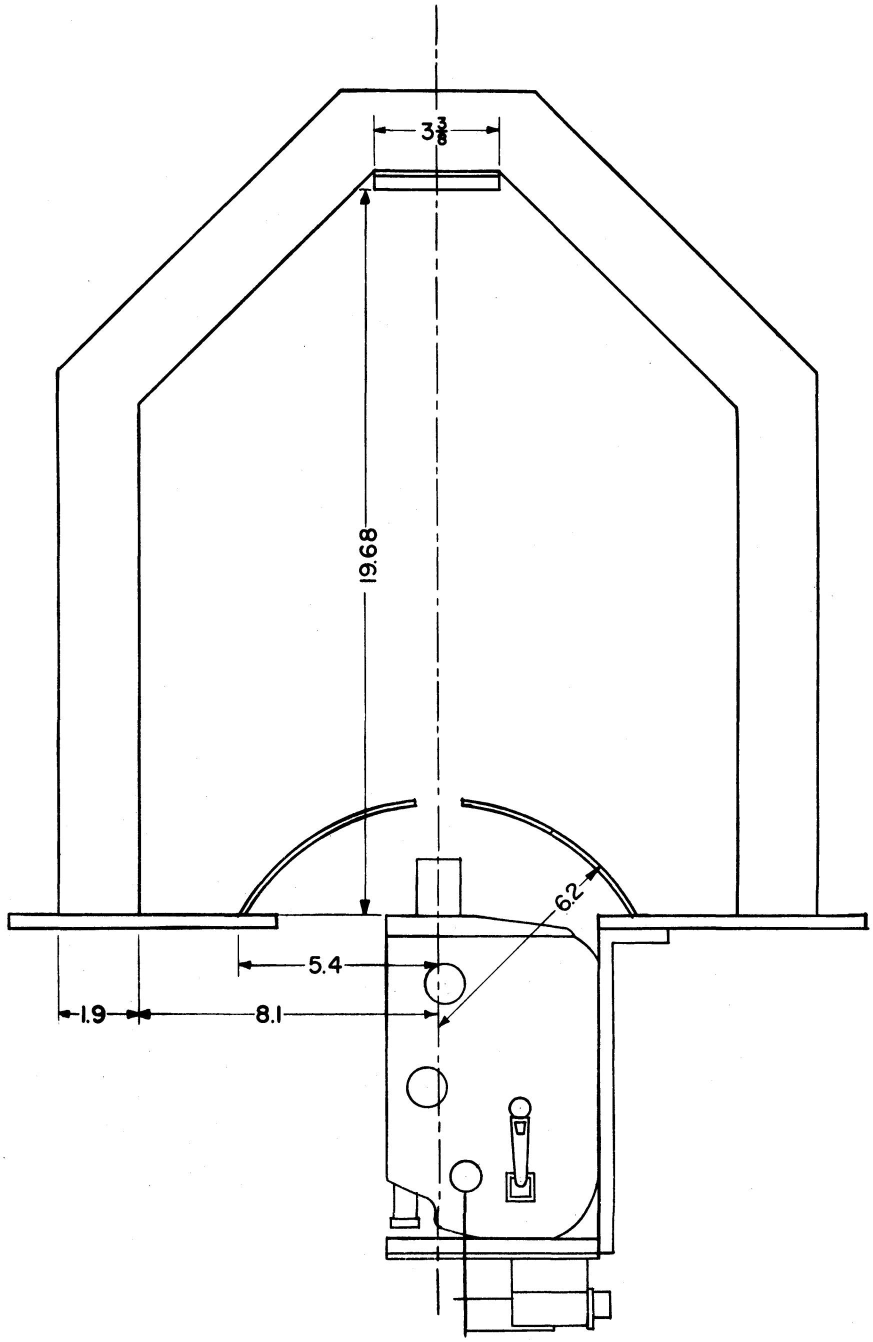
APPENDIX A
STOFFREGEN'S CAMERA



APPENDIX A
STOFFREGEN'S CAMERA



APPENDIX B
PROPOSED DESIGN



SCALE IN INCHES

APPENDIX B
PROPOSED DESIGN